Effects of ENSO Climate Variability on Terrestrial Hydrologic Systems: Merging Regional Remote Sensing and Simulation Modeling

Project Summary
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NRA-97- MTPE-12 Priority Topic 4:
Understanding Seasonal-to-Interannual Variability in Terrestrial Hydrologic Systems

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Project Web Page: http://geo.arc.nasa.gov/sge/casa

Background and Objectives:

Strong El Niño Southern Oscillation (ENSO) events now affect the growing human population throughout the world. To address this issue, a multi-year satellite data set for the global land surface exists in a form adequate to facilitate development of models to aid in short- to medium-term climate-hydrology forecasting. The research study we propose is aimed at using these remote sensing data sets, together with other land surface data and simulation model predictions, to improve our understanding of the relationships between land surface hydrology, terrestrial production, and interannual climate variability. We intend to take advantage of more than a decade of monthly (8-km) global satellite "greenness" data from the NOAA Advance Very High Resolution Radiometer (AVHRR) in focused studies of ten regional (> 10^4 km^2) test areas located throughout the world. Satellite data sets will be analyzed together with historical climate data from weather station archives, plus regional maps of land cover and human use. From this geographic basis, we will also generate simulation model estimates (see Potter et al., 1993; Potter, 1997) for hydrologic fluxes (evapotranspiration, soil water storage and runoff) and terrestrial productivity for validation against available field study data, in order to improve the foundation for assessments of the ENSO effects on regional drought conditions.

Main Science Questions:

In our world-wide hydrologic analysis of regional pattern and process, we will address the following science questions:

Has regional hydrology changed significantly during the past decade of ENSO events in both managed agricultural and natural landscape areas?

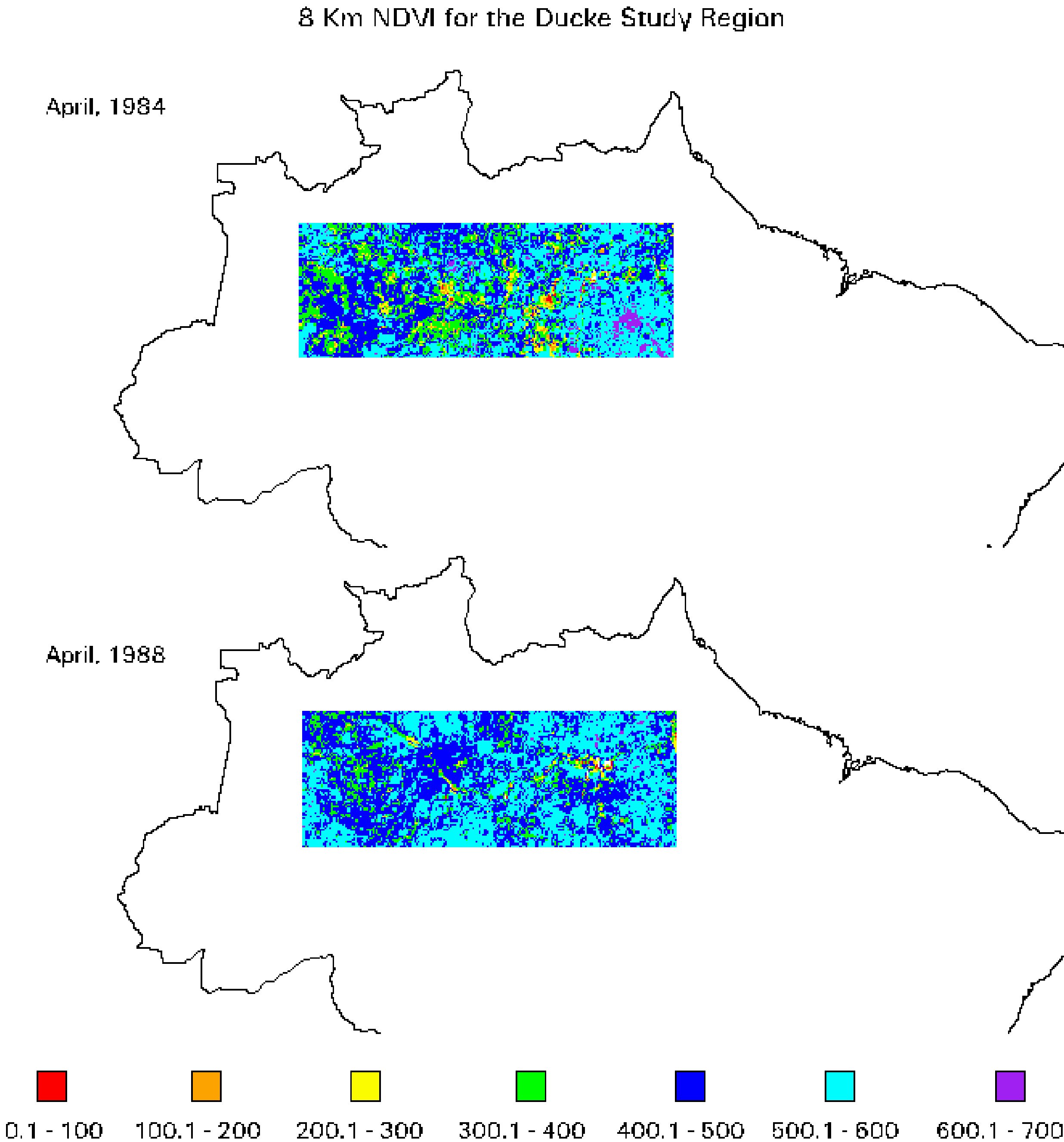
How does short-term (one-to-ten years) variability in climate affect predicted evapotranspiration and runoff in terrestrial landscapes, particularly in areas of extensive human land management?

What is the relationship between climate anomalies (including ENSO) and the timing and length of growing season evapotranspiration in both managed agricultural areas and natural landscapes?

Can variability in terrestrial hydrology and production be forecasted accurately based on short-term climate fluctuations and land cover dynamics over regional scales?

Key Assumptions:

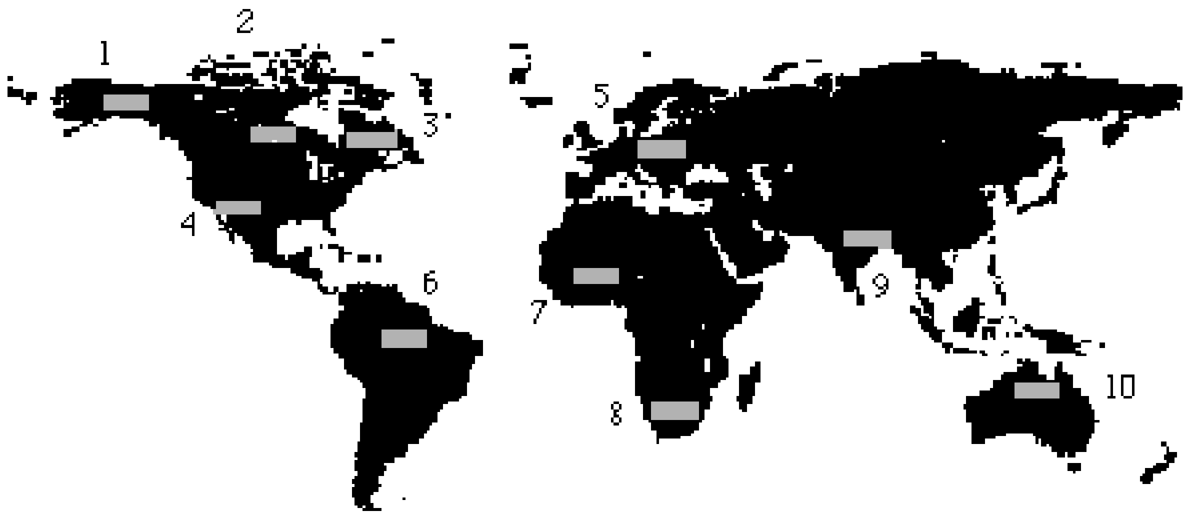
Vegetation cover can play a major role in regional hydrologic systems. Notable examples of this role have been observed in the boreal forest zone where physiological measurements during BOREAS show that atmospheric desiccation can result from the forest's strong biological control limiting surface evaporation (Hall et al., 1996). At the other extreme, climate model experiments suggest that tropical forests contribute significantly to recycling of moisture between the atmosphere and deep soils (LBA, 1996). Moreover, climate-hydrology-vegetation relationships in tropical zones are not static from year to year. This presumption is illustrated in the figure below which shows potential regional drought effects in terms of NDVI following the 1983 El Niño Southern Oscillation (ENSO) over the central-eastern Amazon.



Comparison of seasonal NDVI over the central-eastern Amazon region from 1984 and 1988 for the 5º latitude by 15º longitude area centered on Manaus, Brazil. Effects of the strong 1983 ENSO event are detectable in the 1984 image as areas of comparatively low vegetation greenness. Compiled by V. Brooks at the NASA Ames Research Center.

Research Approach:

A core technical approach for this research is based on autocorrelation time-series analysis of climate with satellite "greenness" data and simulation model results of terrestrial hydrologic flows in ten regional areas. These areas have been selected based on the richness of available spatial data (climate, land cover, and soils) and the potential for important hydrologic consequences of seasonal to interannual climate variability in recent years. We will focus our studies on both meteorological drought and agricultural drought. To better understanding the effects of drought world-wide, evaluation of up-scaling techniques from the landscape to regional levels for hydrologic pattern and process will be a main outcome of this research. Our approach is based on use of frequency distributions for spatially discriminated hydrologic response units as a method of up-scaling from the site level to the landscape and regional levels.

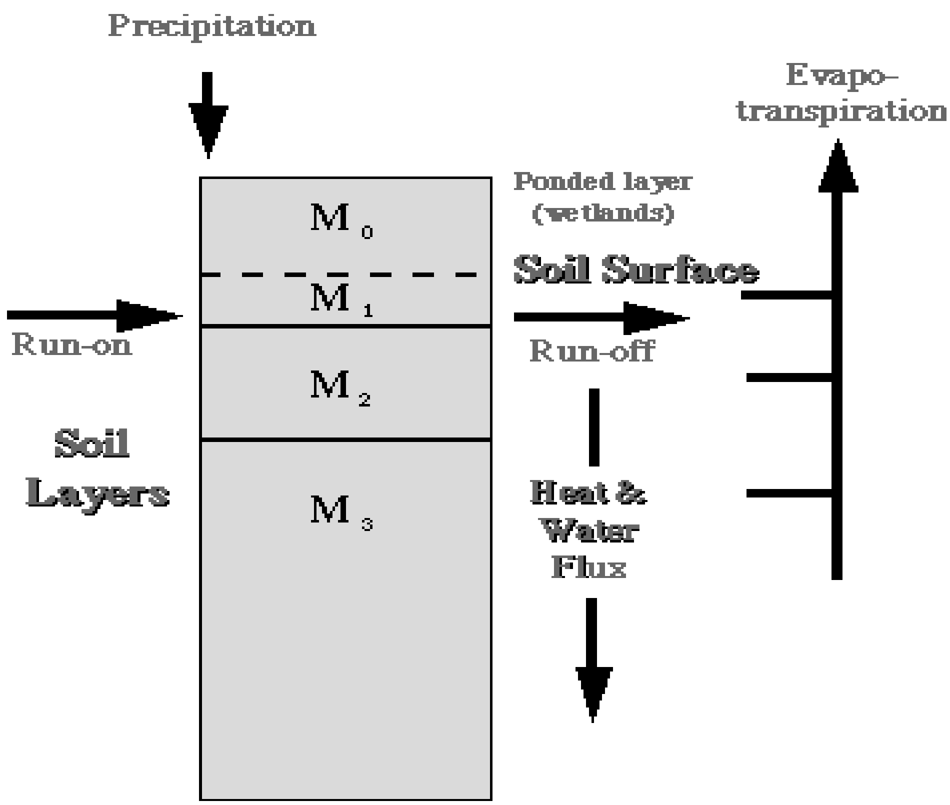


Ten eco-climatic regions selected for studies of terrestrial hydrology, production and climate fluctuations. Selection of regional locations follows the analysis of Koch et al. (1995) for terrestrial transects of importance to global change research. The majority of these regional areas includes at least one intensively studied hydro-climatological research site, as listed. Codes are: 1 eastern Alaska, Toolik Lake, USA; 2 central Canada, BOREAS Northern Study Area; 3 eastern Canada, Shefferville, Québec; 4 southwestern U.S., Sevilleta LTER, New Mexico, USA; 5 eastern Europe; 6 central Amazon, Ducke forest, Manaus, Brazil; 7 western Africa, HAPEX Sahel sites; 8 southern Africa, Nylsvley, RSA; 9 southern Asia, Chaki, India; 10 northern Australia, Tennant Creek.

Modeling Studies:

Our terrestrial hydrologic and production model, called NASA-CASA (Carnegie-Ames-Stanford Approach) model was designed originally as an computerized representation of land surface water, carbon and nitrogen cycles driven by satellite data (Potter et al., 1993). The NASA-CASA spatial framework can be supported by a raster-based geographic information system (GIS) of practically any type. The most recent global version developed at NASA Ames Research Center (see Potter and Klooster, 1997) runs on a daily or monthly time interval to simulate seasonal patterns in evapotranspriation, runoff, soil moisture storage, plant carbon fixation, nutrient allocation, and trace gas production.

The water balance and soil hydrology components of NASA-CASA are designed as a daily multi-layer model of soil moisture content (Potter et al., 1997). We represent the soil profile as a series of three layers: surface organic matter, topsoil (0.3 m), and subsoil to rooting depth (1 to 10 m). These layers can differ in soil texture, moisture holding and retention capacity. We model daily and monthly water balance in the soil as the difference between precipitation (PPT) or volumetric percolation inputs, and potential evapotranspiration and drainage output for each layer.



Structure of NASA-CASA water balance and soil hydrology components (Potter, 1997).

References:

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